COMPARATIVE STUDY OF OUTCOME FOLLOWING PRIMARY ZONE II FLEXOR TENDON REPAIR BY FOUR STRAND CRUCIATE CORE SUTURES AND EARLY MOBILISATION PROTOCOL WITH OTHER PROTOCOLS

– A PROSPECTIVE STUDY

Dissertation submitted to

THE TAMILNADU DR.M.G.R. MEDICAL UNIVERSITY

In partial fulfillment of the regulations

for the award of the degree of

MCh BRANCH – III

PLASTIC AND RECONSTRUCTIVE SURGERY

INSTITUTE FOR RESEARCH AND REHABILITATION OF HAND

AND

DEPARTMENT OF PLASTIC SURGERY

CHENNAI - 600 001

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Dr. ARVIND MAHARAJ.P.M

Registration No. 18102051

INSTITUTE FOR RESEARCH AND REHABILITATION OF HAND

AND

DEPARTMENT OF PLASTIC SURGERY

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CERTIFICATE

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Certified that this dissertation is a bonafide work of **Dr.ARVIND MAHARAJ.P.M,** Post Graduate in M.Ch. Plastic and Reconstructive Surgery during 2010 – 2013 at the Institute for Research and Rehabilitation of Hand and Department of Plastic Surgery, Govt. Stanley Medical College. This study was done under my supervision and guidance.

Prof. Dr.S.Geethalakshmi. MD., Phd.,
Dean
Stanley Medical College
& Hospital,
Chennai.

Prof.J. Mohan. M.S.,M.Ch.,
Professor and HOD,
IRRH &
Dept of Plastic Surgery,
Stanley Medical College,
Chennai.

DECLARATION

I solemnly declare that this dissertation titled

"COMPARATIVE STUDY OF OUTCOME FOLLOWING PRIMARY ZONE II FLEXOR TENDON REPAIR BY FOUR STRAND CRUCIATE CORE SUTURES AND EARLY MOBILISATION PROTOCOL WITH OTHER PROTOCOLS – A PROSPECTIVE STUDY"

Is a bonafide work done by me in IRRH and Dept. of Plastic Surgery, Stanley Medical College & Hospital, Chennai under the guidance and supervision of

Prof.J.Mohan, M.S.,M.Ch.,

Professor & Head of the Department, IRRH and DPS
Stanley Medical College, Chennai.

This dissertation is submitted to the Tamil Nadu Dr.MGR Medical University, Chennai in partial fulfillment of the university requirements for the award of the degree of M.Ch., Plastic and Reconstructive Surgery.

Place : Chennai
Date :

Dr.ARVIND MAHARAJ.P.M
Postgraduate Student
IRRH and DPS,
Stanley Medical College, Chennai.

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INSTITUTIONAL ETHICAL COMMITTEE,
STANLEY MEDICAL COLLEGE, CHENNAI-1

Title of the Work: COMPARATIVE STUDY OF OUTCOME FOLLOWING PRIMARY ZONE II FLEXOR TENDON REPAIR BY FOUR STRAND CRUCIATE CORE SUTURES AND EARLY MOBILISATION PROTOCOL WITH OTHER PROTOCOLS – A PROSPECTIVE STUDY

Principal Investigator :Dr. Arvind Maharaj. P. M.
Designation : PG in M.Ch(Plastic Surgery)
Department : Department of Plastic Surgery
Government Stanley Medical College,
Chennai-1

The request for an approval from the Institutional Ethical Committee (IEC) was considered on the IEC meeting held on 13.07.2011at the Council Hall, Stanley Medical College, Chennai-1 at 2PM.

The members of the Committee, the secretary and the Chairman are pleased to approve the proposed work mentioned above, submitted by the principal investigator.

The Principal investigator and their team are directed to adhere to the guidelines given below:

1. You should inform the IEC in case of changes in study procedure, site investigator investigation or guide or any other changes.
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4. You should abide to the rules and regulation of the institution(s).
5. You should complete the work within the specified period and it any extension of time is required, you should apply for permission again and do the work.
6. You should submit the summary of the work to the ethical committee on completion of the work.

23/3/13

MEMBER SECRETARY,
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COMPARATIVE STUDY OF OUTCOME FOLLOWING PRIMARY ZONE II

BY ARVIND MAHARAJ P.M. 18102051 M.CH. PLASTIC RECONSTRUCTIVE SURGERY

INTRODUCTION

Injuries to the hand are the most common injury that occurs to the human body. Varying from small abrasions to total amputations, the degree of severity of these injuries varies. But the outcome of a poorly treated hand injury is always a disability that severely traumatizes the psyche of the patient.

Flexor tendon injuries are of special mention among hand injuries because their management requires complete and clear knowledge about the anatomy of the flexor tendons, their biomechanics, the various modalities of management, and more importantly what type of treatment the patient is actually in need of.

Among flexor tendon repairs, the hardest is zone II repairs as results of repair in this "NO MAN'S LAND" can be poorer and is prone for more complications. As expected such an area of treatment does have multiple techniques described.

CONTENT

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Injuries to the hand are the most common injury that occurs to the human body. Varying from small abrasions to total amputations, the degree of severity of these injuries varies. But the outcome of a poorly treated hand injury is always a disability that severely traumatizes the psyche of the patient.

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Among flexor tendon repairs, the hardest is zone II repairs as results of repair in this “NO MAN’S LAND” can be poorer and is prone for more complications. As expected such an area of treatment does have multiple techniques described.

This study is an attempt to audit the results of ZONE II flexor tendon repair and management by a suturing technique and management protocol in our institute and compare them with the existing method of repair and management protocols.

Aim of the Study

AIM OF THE STUDY

To evaluate and compare the outcome following primary Zone II flexor tendon repair by four strand cruciate core sutures and early mobilization protocol with other protocols.

Review of Literature

REVIEW OF LITERATURE

The flexion movement of the hand is controlled by a set of intrinsic and extrinsic flexors. The extrinsic muscles are those that are present in the forearm and the intrinsic muscles are those that are present in the hand. The extrinsic flexors of the fingers are the flexor digitorum superficialis (FDS) and flexor digitorum profundus (FDP). The intrinsic flexors are the small muscles of the hand namely the lumbricals & interossei. Flexion of the thumb is a sum function of the Flexor pollicis longus (FPL) which is the extrinsic muscle and the flexor pollicis brevis (FPB) which is the intrinsic muscle.

The extrinsic finger flexors namely the FDS and FDP are called so because of the arrangement of the muscle bellies of these two muscles. The FDP muscle belly is present in a deeper plane just above the pronator quadratus and the bones of the forearm. The flexor pollisis longus is in this plane. The FDS muscle belly is in a layer superficial layer to the FDP, along with pronator teres muscle. The flexors of the wrist namely the flexor carpi radialis and flexor carpi ulnaris along with Palmaris longus lies in the plane just deep to the deep fascia just above the FDS muscles.

All these flexors originate as a common origin called the 'common flexor origin' from the medial epicondyle of the humerus, the adjoining ulna, and the interosseous membrane. They all end by getting inserted to various phalanges in the hand as tendons which pass under the flexor retinaculum in the wrist and the palm.

ANATOMY OF FLEXORS

Forearm*:* Flexor Digitorum Superficialis

The FDS muscle is the superficial of the deep layer of the anterior compartment of forearm. The muscle has two heads

a. The humero-ulnar head. It originates from
    i. the medial epicondyle of the humerus
    ii. coronoid process of the ulna;
b. The radial head: It originates from
    i. anterior oblique line of the radius.

FDS muscle forms four tendons in the distal forearm. These pass under the flexor retinaculum of the wrist and into flexor aspect of the fingers. The tendons are arranged such that the tendons for the ring and middle fingers are superficial to the tendons for the index and little fingers. At near the base of the proximal phalanx, the tendon of FDS splits and forms two slips which pass behind (dorsally) each side of the tendon of FDP and gain insertion into the shaft of the middle phalanx. FDS primarily flexes the proximal interphalangeal joint. It also flexes the metacarpophalengeal joints and also the wrist joint. At the level of the proximal forearm the ulnar artery and the median nerve pass deep to the muscle between its two heads.

It is innervated by the median nerve (C8, T1) and is vascularized by the branches of the radial and ulnar arteries.

Fig: 1 Origin and insertion of FDS

Flexor Digitorum Profundus

The FDP muscle is deeper to the FDS. It takes its origin from

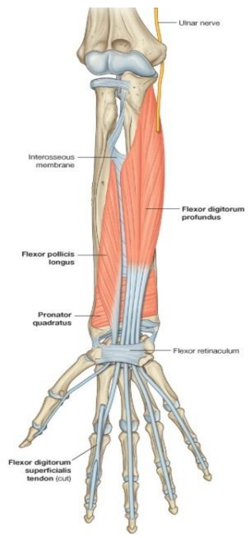
1. The ulna bone on its medial and anterior sides.
2. The part on the anterior surface of the interosseous membrane adjacent to the ulna.

The FDP muscle ends as four tendons one to each finger. The tendons pass under the flexor retinaculum, viz., carpal tunnel of the wrist and into flexor aspect of the fingers. The tendons of the FDP are deep to the tendons of the FDS muscle. At the level of the base of the proximal phalanx of each finger the tendon of the FDP passes through the two slips of the FDS tendon. They then get inserted into terminal phalanx of each finger. The index finger FDP may be present as a separate belly.

The lumbrical muscles take their origin from the FDP tendons in the palm. The FDP muscle has a dual innervation. The lateral half of the FDP muscle, which forms the tendons for the index and middle fingers, is innervated by the median nerve (anterior interosseous nerve). The medial half which forms the tendons for the ring and little fingers is supplied by the ulnar nerve. The muscle is vascularized by branches of the radial and ulnar arteries.

FDP is the primary flexor of the distal interphalangeal joint. It also flexes the proximal interphalangeal joint, the metacarpophalangeal joint and the wrist as well.

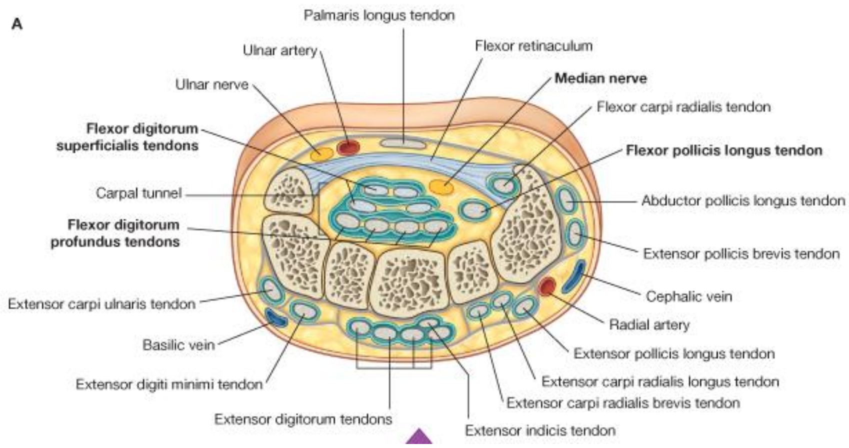
Fig: 2: Origin & insertion of FDP



WRIST LEVEL

At the level of the wrist, the tendons travel under the carpal tunnel. The flexor tendons are so arranged that the deepest tendon flexes the farthest joint. Thus we have the FDP tendons are the deepest. The FDS tendons of the index and little fingers are arranged superficial to the FDP tendons. The FDS tendons of the middle and ring fingers are above them. The median nerve, at this level, is the most superficial structure under the carpal tunnel.

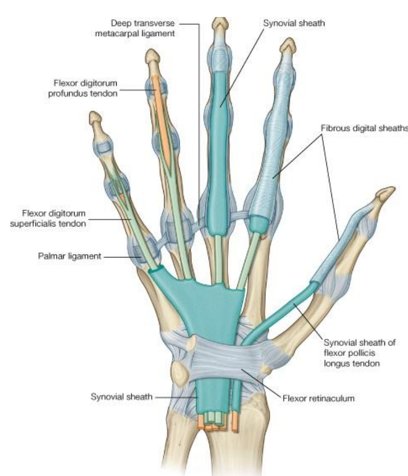
Fig 3: Arrangement of Flexor tendons at the wrist



PALM LEVEL

Beyond the carpal tunnel the tendons of FDS and FDP are arranged deep to the palmar aponeurosis and the neurovascular bundles. The FDS is superficial to the tendons of the FDP. The FDP tendons give origin to the lumbricals of each finger. At the level of the metacarpophalangeal joint the tendons pass into the fibrous flexor sheath system of the fingers.

Fig:4:Synovial sheath of tendons in palm

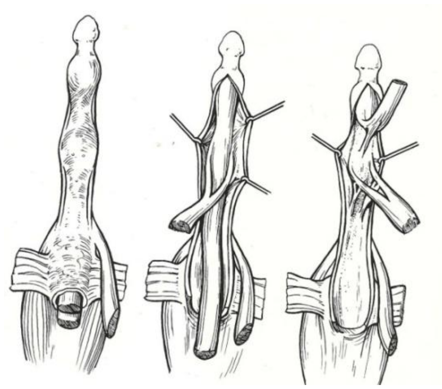


FINGER LEVEL

In the fingers the tendons are covered a synovial sheath and they travel in a fibro-osseous tunnel formed by the fibrous flexor sheath. The FDP tendon which is initially deep to the FDS tendon becomes superficial when the FDS tendon splits into two at the level of base of the proximal phalanx. It then travels distally and inserts into the terminal phalanx.

The FDS meanwhile divides into two slip forming the 'C*amper's chiasma*' and inserts into the middle phalanx.

Fig:5:Tendons in finger



Retinacular system of the hand

The fibrous tissue architecture of the hand forms a series of pulleys at 3 levels.

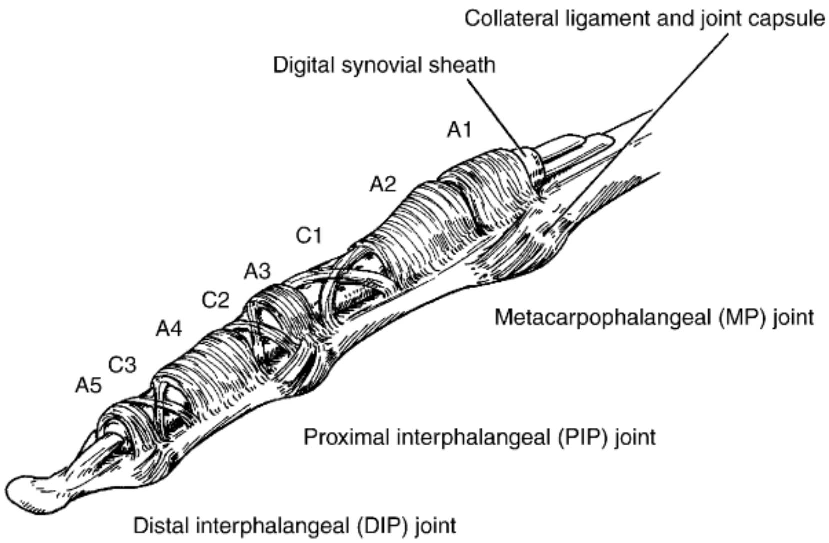
1. Wrist
2. Palmar aponeurosis
3. Digital pulley system

The transverse carpal ligament forms the wrist pulley. At the level of the palm the palmar aponeurosis forms an apron protecting the palm and restraining the tendons in place. Beyond them in the fingers, is the digital pulley system.

Digital pulley system:

This is formed by four or five discrete annular pulleys and three cruciate bands. The most proximal pulley A1 begins 0.5 cm proximal to the metacarpophalangeal joint. It is anchored to the volar plate and the proximal phalanx. The second annular band A2 is just distal to it. This is the largest of the pulley system. It extends for nearly the whole proximal half of the proximal phalanx. The first cruciate pulley C1 lies distal to A2. It is proximally placed to the proximal interphalangeal joint. The third annular pulley A3 lies over the proximal interphalangeal joint. It arises from the proximal interphalangeal joint volar plate. The second cruciate pulley C2 is placed at the base of the middle phalanx. The fourth annular pulley A4 is located over the middle one third of the middle phalanx. The fifth annular pulley A5 is present over the distal interphalangeal joint. The pulleys are strategically placed to maximize the efficiency of the tendon and movement system and prevent bow-stringing effect of the flexor tendons.

Fig:6: Pulley system of the finger



The microstructure of the flexor tendon

Tendon consists of two components namely cellular and Acellular elements.

The cellular elements are

1. fibroblasts
2. spindle-shaped cells, which produce collagen and reorganize the extracellular matrix.

The Acellular elements are

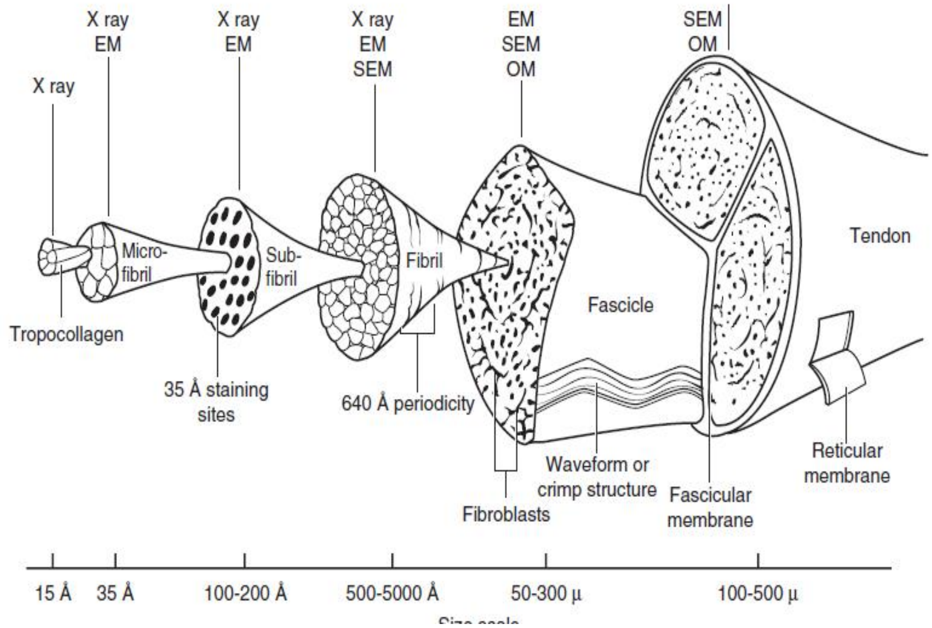
1. Water (60%–80% of the wet weight)
2. Collagen (86% of dry weight)
3. Proteoglycans (1%–5% of dry weight)
4. Elastin (2% of dry weight)

Collagen Type I, is the most common type in tendon. It is formed by three polypeptide chains cross-linked by covalent and hydrogen bonds. The amount of cross-linking varies at different areas of the tendon leading to various different mechanical properties of the tendon at different levels. The number of crosslinking decreases in the following order

1. Middle portion of the tendon.
2. Tendon–bone insertion
3. Musculo-tendinous junction.

A *microfibril* is formed by crosslinking of 5 collagen molecules. *Subfibrils* are formed by groups of microfibrils. *Fibrils* are formed by groups of microfibrils. A *tendon fascicle* is formed by closed packed fibril bundles in a proteoglycan and water matrix. *Fascicles* bound within the endotenon forms the tendon. The neurovascular structures are present in this layer. The epitenon, which is the synovial membrane of the tendon, sheaths it completely. It secretes the synovial fluid which helps to nourish the tendon and its smooth gliding.

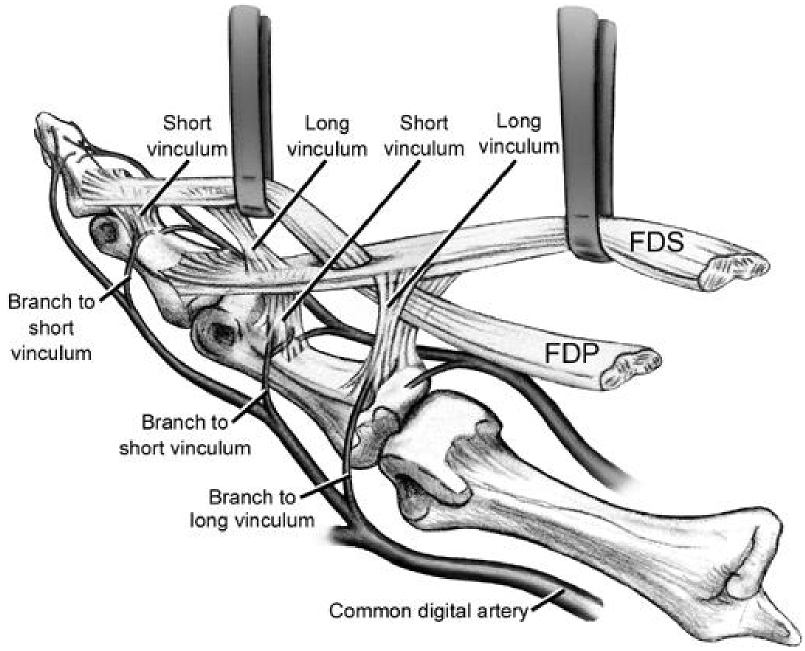
Fig:7:Micro anatomy of the tendon



Mesotenon & Vincula

Synovial sheaths are formed during embryonic development, wherever the tendon is subjected to restraint and friction by the retinacula. The synovium forms a double walled sac when the tendon invaginates into it. The segmental vessel of the tendon comes to lie within the wall of the sac to form a mesentry- like *mesotenon*. During the course of time the mesentry refines itself to tiny flexible band or *vincula*. It is long and flexible like a cord at places where there a differential excursion between the tendon and the bone is more. These are the *vincula longa*. The residual mesotenon form the *vincula brevia* at site of bony insertion.

Fig:8:Vincula system of the finger.



Tendon nutrition

As such the metabolic demands of the tendon is low due to the low cellular population. Hence a tendon can survive with minimal nutritional support. The nutrition of the tendon is provided by three systems.

1. The *longitudinal vessel* that comes along the tendon. It enters the tendon at the musculotendinous junction and at the site of bony insertion.

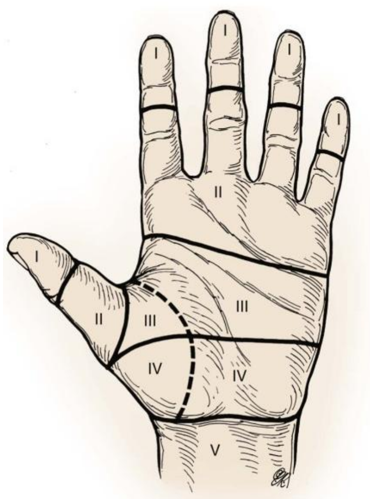
2. The *segmental vessels* which supply the tendon through the mesotenon and the vinculae.

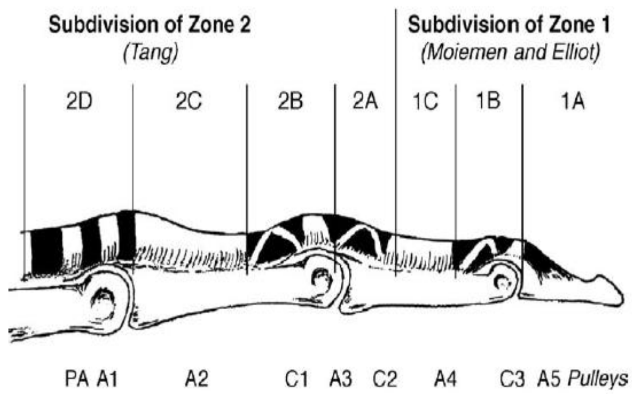
3. The *synovial fluid* present in the synovial sheath.

Zones of flexor tendons

Anatomic location of flexor tendons are referred to a zones. There are 5 zones. This was originally described by *Verden*. There are modifications mentioned.

Fig:9, 10:Zones and sub zones of flexors of the hand





Zone I:

Proximal extent: insertion of the FDS tendons

Distal extent: insertion of the FDP tendon

Contents: FDP (FDP) tendon

Zone II

Proximal extent: the proximal edge of the A1 pulley

Distal extent: insertion of the FDS tendons

Contents: FDS & FDP tendon, the Capmer's chaisma, and the vincula.

Bunnell referred to this region as the “NO MAN’S LAND”

This region is notorious for the increased incidence of adhesions between the tendons as they are enclosed in a tight fibro-osseous tunnel. The blood supply for the tendons in this region is also limited.

Zone III

Proximal extent: distal edge of the transverse carpal ligament.

Distal extent: the proximal edge of the A1 pulley

Contents: FDS & FDP tendon,

Zone IV

Lies beneath the transverse carpal ligament and its content. This space is also narrow and hence can cause increased incidence of complications.

Zone V

Proximal extent: musculotendinous junction

Distal extent: proximal edge of the transverse carpal ligament.

Sub zones of zone II

Sub divisions to the zone II were proposed by many authors. The most commonly used system is proposed by Tang et. al.

It is as follows

IIA – part of zone II below the A4 pulley

IIB – part of zone II below the C1 pulley

IIC– part of zone II below the A2 pulley

Tang et al., proposed only FDP repair in zone IIC and distally caused lesser complications

Biomechanics

BiomechanicallyA2 & A4 pulleys are the most important. Pulley efficiency is significantly decreased with loss of the A2 (or) A4 pulley. However disruption of the Al, A3 or A5 (Minor pulleys) has little effect on overall efficiency unless all are divided.

Finger position and flexor tendon injury

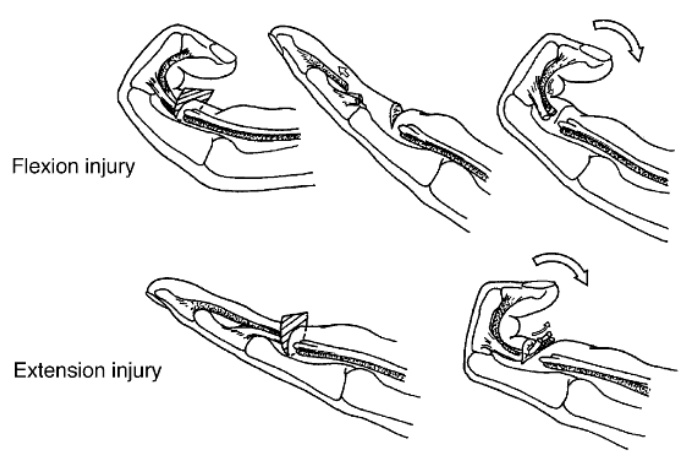
Flexion injury:

The cut tendon end is actually distal. Hence a distal window exposure is needed

Extension injury:

The cut injury is usually proximal. The distal end can easily delivered out while the proximal end will recede even more proximally. Hence a proximal window dissection will be needed.

Fig:11:Finger position and flexor tendon injury



Tendon Healing

Healing of the flexor tendons is by two mechanisms. Both of these play an effective if not an equal part.

They are

1. Intrinsic tendon mechanism
2. Extrinsic mechanisms

Both these mechanism occur simultaneously. But which mechanism dominates is determined by various factors like

1. type of injury
2. surgical technique
3. Post-operative rehabilitation protocols.

Intrinsic Healing

It occurs inside the substance of tendon. It is carried out by the tenocytes present in the epitenon and endotenon of the tendon. The nutrients needed for this process is provided by

1. intratendinous blood supply
2. synovial diffusion.

Extrinsic healing

It is brought about by the tissues residing outside and adjacent to the flexor tendon.

The following processes take place.

1. inflammatory cell activation
2. revascularization
3. Fibroblastin growth.

The end result is the formation of adhesions which act as a scaffolding for the new vessels to reach the tendon. But this results in tendon excursion limitations. Nutrition supply by synovial diffusion has been proved to be more important for tendon healing than vincular blood supply. Vascular injury leading to poor clinical results are reported by Amadio et al.

There are three phases of healing of a tendon. They are

1. Stage of Inflammation (48 to 72 hours)
2. Stage of proliferation of fibroblast (5 days to 4 weeks)
3. Stage of remodeling

Tenocytes from the tendon and the fiibroblasts from the extrinsic healing mechanism migrate to the site of repair. They start synthesis of collagen. Initially randomly arranged fibrils of type 3 collagen are deposited which are later replaced by type 1 collagen which are laid down in an organized manner. Vascularity is established by the simultaneous occurrence of angiogenesis. When collagen production and collagen removal equate each other remodeling begins. Remodeling is well established by the 4th week and continues well into the 6th month in a few cases. There is a rapid increase in tendon strength after the 21st post-operative day.

Motion and application of stress to the tendon facilitates

1. Collagen reorganization
2. Improved repair strength
3. Tendon healing as such.

This is identified is studies that quantified the total DNA content in the repair site and adjacent tendon sheath. It showed an increase in cases where stress and motion is applied. There is no such increase in cases where an immobilization protocol is followed.

Repair Strength

At the time of the repair the tendon's "repair strength" increases in proportion to the number of strands of the core suture that runs across the repair site. An ideal suture material should be strong, stretch resistant, good knot holding, easy to handle and should have minimal tissue reaction. Braided polyamide sutures are the most suited for the job, even though polypropelene is the most commonly used suture material.

4-0 core sutures are made. Epitenon or co-aptation sutures with 6-0 sutures are taken.

Epitenon sutures help by

1. Smoothening out the co-apted edges.
2. Increasing strength by upto 10 – 50%
3. Prevents gaping

The repair strength of the flexor tendon is decreased between day 5 – 18. This is because of the gelatinous degradation of the tendon ends in the early week of the repair. The tendon is weakest at around 4-5 days and gradually increases in strength. It is only after day 19 that the strength increases in proportion to the stretch applied to it. With this in mind, proponents of early mobilization protocols advocate multistrand suturing techniques, to reduce the rates of rupture.

Suture Site Gaping

Tendon repair site gaping may lead to

1. Increase in the incidence of adhesion
2. Disruption of mechanical function (due to tendon lengthening)
3. Increases chance of rupture.

Gapping of more than 2 mm or more is often used to determine repair failure. The “gold standard” for measurement of the strength of tendon repairs is gapping after application of cyclic loads. Ultimate tensile strength is the load required to cause tendon rupture.

HISTORY OF FLEXOR TENDON REPAIR

The records from antiquity show that Hippocrates and other ancient physicians did not recognize the tendon as a distinct structure.

Galen who wrote, ‘‘*I found one of the gladiators called horseman with a transverse division of the tendon on the anterior surface of the thigh, the lower part being separated from the upper, and without hesitation I brought them together with suture.*’’ can well be considered as the first physician to describe tendon suturing. He greatly influenced the great Muslim physician– philosopher of the eleventh century - *Avicenna*, who is described as the first advocate of tendon suturing. Though reports of successful tenorrhaphy were present the practice was not common till the 17th century.

Meekren’s experiments in 1682 and those of *Von Haller* recording the effects of trauma on tendons that dealt the death knell to the concept of “no tendon suturing”

John Hunter, in 1767, was the first to perform experiments on tendon healing. These experiments raised a lot of question on the various changes in the morphology, biomechanical properties and other factors affecting tendon healing. These experiments were done with Achilles tendon. Though very different in its anatomical character and environment, these experiments where the harbinger of the era of scientific flexor tendon repair.

Investigations specific to flexor tendon healing were first done by *Bier and Saloman* in 1920.*Hueck's* experiments during the same period produced conflicting results.

Bunnell & Garlock both observed the formation of severe restrictive adhesions in this region. Bunnell described the term **No Man's Land** to describe Zone II in 1934 in textbook "*Surgery of the Hand*" [2nd edition]. He gave a strong caution and strict guidelines for repair of tendons in Zone II repair.

Boyes in 1940, indicated the following features as the cause for failure for repairs in zone II

1. Infection
2. excessive scarring
3. Poorly placed incisions due to flexion contracture.

He advocated delayed flexor reconstruction with tendon graft for these injuries. The first half of the 20th century was mostly an era of tendon grafting rather than flexor tendon repair.

Potenza and Peacock theorized that tendinous healing was mostly an extrinsic phenomenon brought about by adhesions. The fibrous adhesions said to be an essential component of the healing process.

The early 21^{st} century was essentially concentrated on flexor tendon reconstruction with grafts more than repair.

Siler in 1950, reported results of upto 62% good and excellent results of tendon repair in No Man's Land. In 1956, *Posch* reported 87% satisfactory results.

Kleinert, Kutz, et al presentation ''*Primary Repair of Flexor Tendons in No Man's Land*'' at the annual meeting of the American Society for Surgery of the Hand in 1967 is a major reason why flexor tendon repair took precedence over flexor tendon grafting.

This practice increased the number of experiments in tendon healing and suturing techniques for flexor tendons.

Nutrition by diffusion as an effective source was established in these studies.

''Roundingoff'' and healing of lacerated stumps of flexor tendons within the intact digital sheath without peripheral adhesions, was noted by *Matthews and Richards* in rabbits. Similar results were seen in canine models by *McDowell and Snyder.*

Lindsay et al., observed the activity of chicken tendon cell in healing.

Healing of flexor tendon lacerations placed in the synovial cavity of the knee by *Lundborg et al.,* was supported by further studies by the Japanese team of *Katsumi and Tajima.*

The theory that peripheral adhesion or extrinsic healing is not always needed in tendon healing was proved by in- vitro organ culture studies by *Manske, Lesker, Gelberman et al* in the mid-1980s

These studies led to the development of newer techniques in

1. tendon mobilization
2. suturing techniques
3. suture materials
4. mobilization protocols to apply tension on the tendons

Table:1: Contributors to flexor tendon surgery in the later 21^{st} century

Potenza et al	1962-1986	Tendon biology, healing	Stressed the contribution of surrounding sheath to repair site healing
Kleinert et al	1967-present	Early motion rehabilitation	Reported technique of reliable and reproducible postoperative "rubberband" rehabilitation. Also first valid report in U.S. of primary zone 2 repair
Burner	1967-1975	Skin incisions	Zigzag volar approach to digital sheath
Kessler et al	1969-1987	Primary tendon repair	Core suture technique
Ketchum et a	1971-1985	Biology and biomechanics of tendon repair	Experimental study of tendon repair and healing
Lundborg et al	1975-present	Tendon healing, vascularity, nutrition	Advocated concept of "intrinsic" tendon healing, detailed vascularity of flexor tendon
Duran et al	1975-1990	Early motion rehabilitation	Passive motion rehabilitation protocol
Manske et al	1977-present	Tendon biology, biomechanics	Classic studies of tendon nutrition, repair site biology and biomechanics
Leddy et al	1977-1993	FDP avulsion injuries	Classification of FDP avulsions
Lister et al	1977-1986	Rehabilitation, pulley reconstruction	Clinical studies of pulley reconstruction and handling of digital sheath
Gelberman et al	1980-present	Tendon biology, biomechanics, rehabilitation	Classic experimental and clinical studies of tendon repair site biology, biomechanics, vascularty, and rehabilitation
Strickland et al	1982-present	Tendon repair, rehabilitation	Classic clinical and experimental studies of flexor tendon repair and rehabilitation
Silfverskiýld et al	1983-1994	Tendon repair, rehabilitation	Clinical and experimental study of repair site gap formation and rehabilitation
Amadio et al	1984-present	Tendon and pulley biology, biomechanics, rehabilitation	Classic experimental studies of tendon repair site biology, biomechanics, and rehabilitation
Hitchcock et al	1987	Tendon biology, rehabilitation	Experimental study of biologic effect of passive motion rehabilitation
Doyle	1983	Flexor pulley system	Relative importance of each pulley
Mass et al	1989-present	Tendon biomechanics	Experimental study of in vitro repair site biomechanics
Abrahamsson et al	1989-present	Growth factors in tendon healing	In vitro studies of growth factor synthesis during repair site healing and their effects
Seiler et a		Biology of tendon repair	Identification of growth factors in repair, suture methods in tendon repair
Schuind et al	1992-present	In vivo flexor tendon forces	Classic study documenting in vivo flexor forces during digital motion
Diao et al	1995-present	Core and circumferential suture techniques	Experimental study of role of circumferential suture in time-zero repair site strength
Sandow and McMahon	1996-present	Core suture technique	Improved time-zero core suture technique
Boyer et al	1997-present	Tendon biology, biomechanics, rehabilitation	Experimental studies of tendon repair site biology, biomechanics, vascularity, and rehabilitation
Wolfe et a	1999-present	Core suture technique	Core suture technique
Taras	1999-present	Core suture technique	Core suture technique
Leversedge	2000-present	Tendon vascularity and neovascularization after repair	Experimental studies of tendon repair site and insertion site vascularity

TREATMENT OF FLEXOR TENDON INJURIES

TENDON REPAIR

Clinical assessment

History, physical examination and imaging can almost always clinch the diagnosis in cases of hand injuries. Hence an emergency exploration in the emergency room is rarely needed.

Management starts with clinical assessment by the ATLS protocols. Hand examination comes only after a thorough history and a secondary survey.

Points noted include

1. position of the finger at the time of injury
2. type of injury
    i. sharp
    ii. blunt
    iii. crush
    iv. avulsion
3. place of injury
    i. home
    ii. work
        1. industrial
        2. agricultural
    iii. road side
4. soft tissue condition

Physical examination is done to assess for

1. tendon injury
2. nerves
3. vascularity of the finger and
4. assessment for fractures

Imaging

X-Ray imaging is the only modality needed in acute injuries to detect fractures. Other modalities are more useful in special circumstances and in post-operative management.

Ultrasonography:

Noninvasive, and non-ionizing

It can help

1. localize cut tendon ends
2. assess the integrity of a repair
3. assess adhesions in a dynamic study

Computer Tomography

1. can diagnose pulley rupture
2. Distorted images in presence of tissue edema, hematoma.

Magnetic Resonance Imaging

1. gold standard
2. needs special coils for fingers

3. Can diagnose

    a. cut ends

    b. integrity of repair

    c. distinguish ruptures from adhesion

    d. pulley ruptures

Time of the repair

Tendon repair can be classified into four types based on the time of repair.

S.no	Duration from injury	type
1	Within 12 hours	Primary
2	Within 10 – 14 days(before skin wound heals)	Delayed primary
3	Within 2- 4 weeks	Secondary
4	After 4 weeks	Late secondary

Repair should be attempted at the earliest possible moment.

Best results are obtained for primary repair. Poorer outcomes are seen with secondary repairs. The worst outcomes are seen with delayed primary repairs.

Disruption of tendon gliding occurs after 4 weeks due to muscle fibrosis, contraction of the tendon and swelling of the proximal cut end of the tendon.

Guidelines for repair

1. Non traumatic technique.
    a. Minimal and gentle handling.
    b. Handling only the cut ends.
    c. Using precision instruments.
2. Using magnification loupes of appropriate magnification.
3. Repair of digital nerves is a must as a dis-aesthetic finger is usually stiff.
4. Vascular repair is must in cases of vascular compromise.
5. Rigid skeletal stabilization must be attempted in cases with fractures.

Contra-indications for tendon repair

These are very few

1. Severe contamination which might lead on to infections
2. Loss of adequate soft tissue cover for the tendon repair site
3. Patients with poor cognition who cannot be made compliant for the post-operative therapy protocols.

Pre-operative counseling

A session of interaction with the patient and relatives is a must to explain

1. The nature of the injury.
2. Surgery to be attempted.

3. The extensive post-operative therapy protocols and the need for compliance.
4. Need for repeated surgeries.

Anaesthesia

The surgery is usually performed under general or regional anaesthesia like axillary block.

Incision guidelines

1. Finger position at the time of injury is very important

   Flexion injury:

   The cut tendon end is actually distal. Hence a distal window exposure is needed.

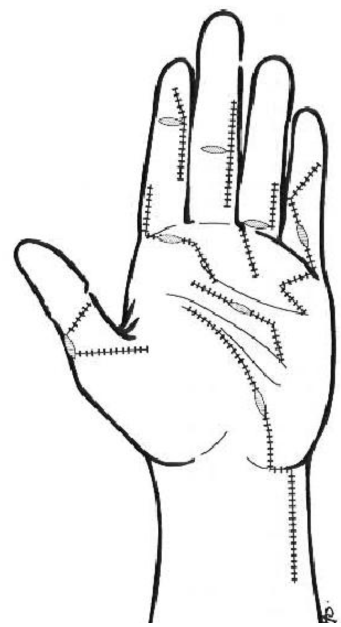
   Extension injury:

   The cut injury is usually proximal. The distal end can easily delivered out while the proximal end will recede even more proximally. Hence a proximal window dissection will be needed.

2. Try to include the laceration in the incision, but if that is not possible try to raise flaps of good vascularity "*do not be a slave to the laceration*"

3. A good exposure precludes good result.

Fig:12:Incisions in the hand



Fibrous flexor sheath and pulley systems

Synovial windows are usually made in the C1, C2, C3 pulleys. An‘L’ shaped incision can be made which can be resutured. The A2 and A4 are the biomechanically most important pulleys. If assess through them is needed or if there is restriction of tendon gliding of the sutured site, the pulleys can be VENTED. The pulleys can be vented upto 75% of their length.

Retrieval of flexor tendons

Injury to the vincula will lead to retraction of the cut tendon edges into the palm. The cut end can be retrieved by one of the following techniques.

1. Milking:
    a. Massaging over the tendon pathway towards the laceration along with flexion of the finger and wrist.
2. Instrument retrieval
    a. Skin hook
    b. Hemosatat
    c. Tendon retriever can be used to retrieve the tendon into the wound. This has to be done very carefully as this will damage the tendon edges.
3. Incision made proximally and the tendon is rail-roaded into the defect with a silicon rod or infant feeding tube.

The retrieved tendon is held in place with a needle pierced percutaneously. This also helps to relieve the tension at the repair site. Care is also taken to place the tendons in their proper anatomical position.

Tendon suturing techniques

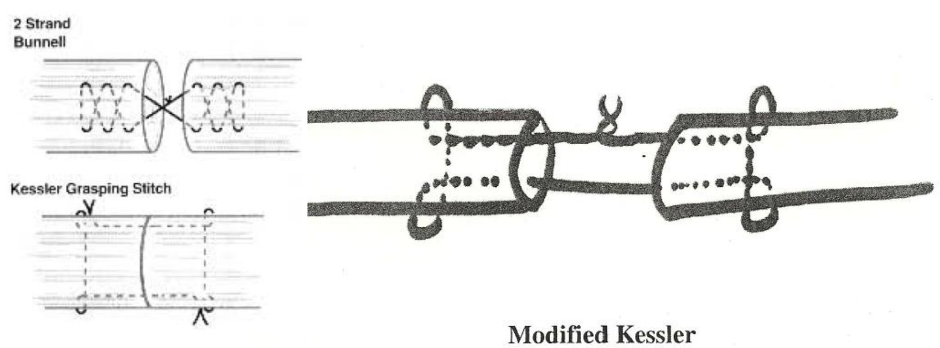
There are two components to a tendon suture.

1. Core suturing
2. Epitenon or co-aptation sutures.

Core suturing

The original older suturing techniques were described using stainless steel wires. The latest techniques use braided polyamide or monofilament polypropelyne sutures. Size is usually 3-0, 4-0. Classical techniques had two strands of sutures which were done with either one suture or a double needled suture. The knot either lies between the cut ends or away from the cut ends. Classical technique most commonly used is the modified Kessler mason suture technique.

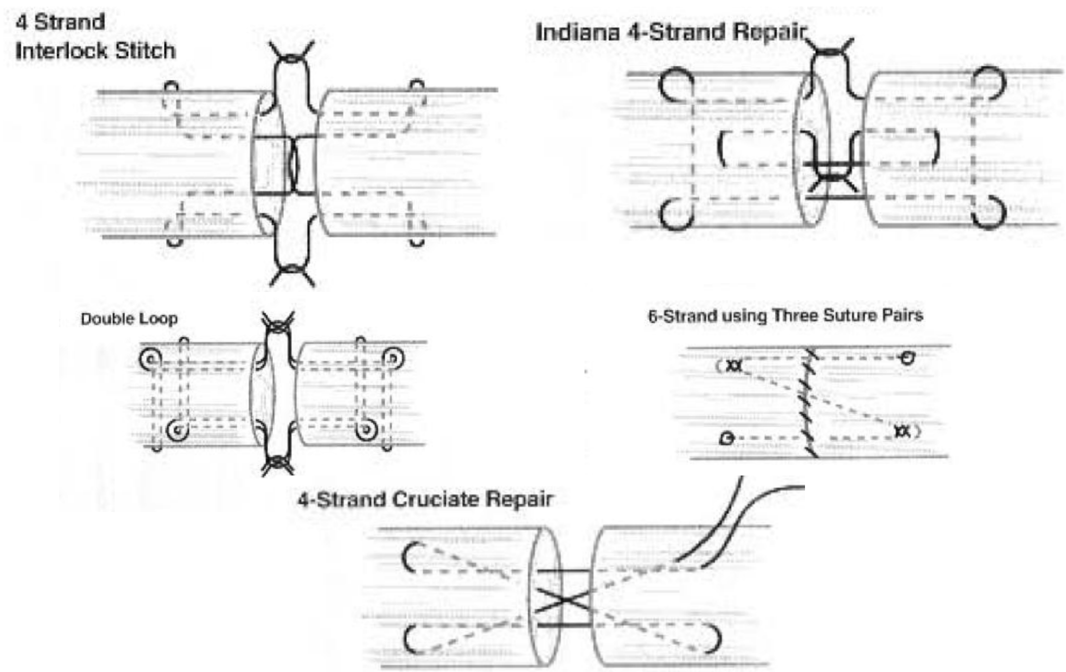
Fig:13:Classical 2 – strand suture techniques



The present day early active motion protocols demand more strands which corresponds to the strength of the repair. Seen below are the various techniques used.

These multi strand techniques provide the increased strength needed for early active mobilization protocols. But as the number of strands increases, the difficulty of the repair also increases. It might also interfere with the healing process

Fig:14: Modern multi – strand suture techniques



Epitenon sutures:

They function to

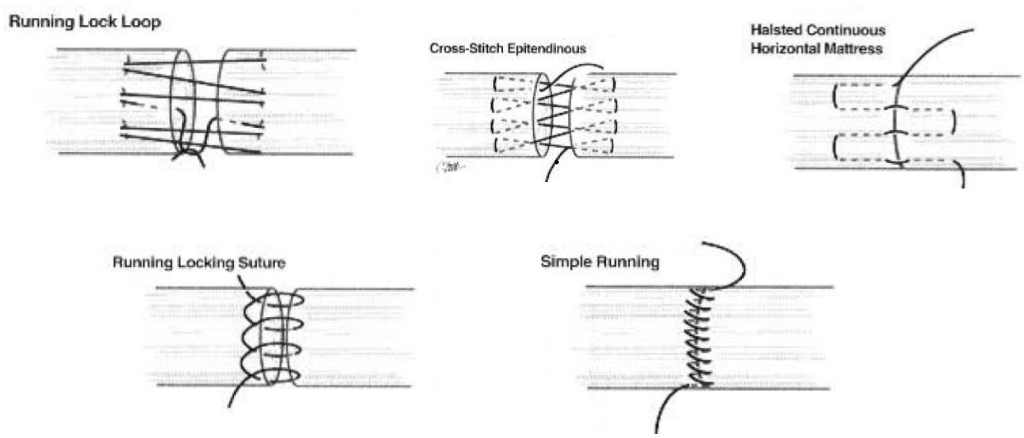
1. Increase the strength of the repair by upto 10-20%. Strength increases proportionately to the number of stitches thrown across the repair.

2. To smoothen out the edges of the repair and hence reduce chances of adhesions and improve smooth gliding.

3. Decreases tendon gapping.

The four most commonly used epitenon sutures, in the order of decreasing strength are

Fig: 15: Epitenon suture techniques



1. Lin – loop locking sutures
2. Cross-stitch of Silfverskiol and May sutures
3. Halstead and lambert sutures.
4. Simple and simple locking sutures.

The epitenon sutures are always used in conjunction with the core sutures. The sutures can be applied core first or epitenon sutures first. Though technically difficult, epitenon first technique produces less bunching of the tendons. Another commonly used technique is the, half posterior epitenon sutures, core sutures and then completion of the anterior epitenon sutures. The sutures are done with the same suture material as the core but sized 5-0 or 6-0.

Other techniques of tendon repair

Other methods under investigation aim to decrease the time and improve results. Some are

1. Silicon sheets as internal or external splints.
2. Nylon mesh as external sleeves.
3. Internal Dacron sheet.

These methods are yet to be established clinically.

Closure of the wound

The following are noted before wound closure.

1. Tendon sheath closure does not seem to provide any advantage.
2. Pulleys have to be reconstructed if damaged.
3. Check for passive glide of the tendon.
4. Nerve repair and vascular repair are completed.
5. Tourniquet is removed and hemostasis is obtained.
6. Skin is closed with monofilament non absorbable sutures.
7. Dry dressing with finger compression and generous padding is given.

Splinting

Splinting is done with wrist in 20 degrees flexion, metacarpohalangeal joints in about 70 degrees flexion and the interphalangeal joint is kept at near extension in a total dorsal blocking splint made of POP or thermoplastic materials or metal. The patient is advised strict hand elevation.

POST-OPERATIVE REHABILITATION PROTOCOLS

Grossly these are classified as two groups

1. Immobilization protocols
2. Early motion protocols.

The early motion protocols are further divided as

1. Classical early motion protocols
2. Early controlled active extension protocols.

Immobilization protocol

Indicated in

1. children
2. adults who are unable to cooperate with physiotherapy
3. associated unstable fractures
4. microvascular repairs.

The splint is a POP or thermoplastic dorsal slab with the wrist in neutral position, metacarpophalangeal joint in about 70 - 90 degrees flexion and the interphalangeal joint in slight flexion with the splint extending beyond the finger tip. It is kept in place for 3week. Following which active mobilization and passive mobilization are gradually started.

Early motion protocols

Experiments have proved that stress applied to the suture site and movement increase tendon excursion, remodeling, healing and decreases adhesion formation. Various protocols have been designed with concept in mind.

The early motion protocols include passive mobilization of the digits, one active motion and another passive motion, controlled unassisted early active movements or unassisted active movements which are started as early as the 3rd post-operative day.

In all these multistrand core sutures with epitenon sutures are used.

Early motion protocols are classified as

1. Classic Early Motion Protocols
    a. Active extension and passive flexion
        i. Kleinert system
        ii. Brooke army splint
        iii. Mayo clinic synergistic dynamic tenodesis systems

All these systems have dorsal extension blocking splint with wrist in 30 degrees – 40 degrees flexion. These splints allow a 70 degrees flexion at the metacarpophalangeal joint and a maximum 0 degrees extension at the interphanalgeal joints. The interphanalgeal joints are kept flexed with rubber bands attached to hooks from the nails to the forearm. They pass through key holes at the distal palmar crease to increase interphalangeal joint flexion in the Brooke army splint. Supervised active extension and relaxing of the finger which allows passive flexion are continued for 25 times every day upto 3 weeks. The rubber bands are removed and the fingers are held at extension with a Velcro band at nights. Splints are removed at 3 weeks and other mobilizations are started.

b. Passive flexion with passive extension protocols

i. Duran – Houser protocol

This system uses controlled separate passive mobilization of the fingers. This method provides better protection between exercise, more differential glide and decreased joint contractures.

2. Early Controlled Active Flexion protocols

a. Strickland's – Indiana technique

b. Silfverskiold and May technique

c. Unassisted early active motion technique of Small, Cullen and Elliot.

All these systems have dorsal extension blocking splint with wrist in 30 degrees – 40 degrees flexion. These splints allows flexion and extension at the wrist, a maximum 0 degrees extension at the interphalangeal joints and around 70 degrees flexion at the metacarpophalangeal joints.

These protocols combine passive mobilization with mild active mobilization started on the 3-5th days. The mobilization is usually in a controlled environment in the first week after which the patient is allowed to continue the same at home. After 3 weeks the splints are removed and the further mobilization exercises are started.

They provide an additional 30-45% and 20-25% excursion of the FDS & FDP tendons at the PIP and DIP joints. Leading to even better results.

Complications

Can be either

1. Early.
2. Late.

Early complications are

1. Infections
2. Problems of wound healing
3. Ruptures
    a. tendon rupture
    b. pulley rupture
4. Poor tendon gliding.

Late complications are

1. Rupture of tendons.
2. Adhesion.
3. Flexion contractures of the interphalangeal joint.
4. Decrease of flexion strength.
5. Altered tendon length.
6. Pulley dysfunction with bow stringing.

The most common complication is adhesion. Incidence is about 20-40%.

Ruptures are another common problem. The rates are 0-9% for classical techniques and around 0-45% for early mobilisation techniques. Ruptures can occur at either day 10 or as late as 6 to 7 weeks. Most ruptures are due to rash "acts of Stupidity".

Joint contractures are usually due to poorly planned incisions and poor compliance for therapy.

But the most dreaded complication is reflex sympathetic dystrophy which is a very rare complication occurring in less than 1%.

ASSESSMENT OF TREATMENT OUTCOME

Flexor tendon repairs are assessed by Functional grading systems The most commonly used systems are

1. The Total Active Motion (TAM) scale of the American society for surgery of the hand.
2. Grossman system II.
3. Louisville classification system.
4. Buck Gramcko's classification system.
5. Strickland's Original and adjusted classification systems.

Agreement between the systems is only fair

The total active motion (TAM) of the American society for surgery of the hand is calculated for each finger by subtracting the total loss of active extension or hyperextension from the total active flexion. Passive motion is also determined. The calculation involves all three finger joints and averages between 260 and 270 degrees, depending on the finger. (Metacarpophalangeal joint -MCP 80 degrees, proximal interphalangeal joint - PIP 110 degrees and distal interphalangeal joint DIP 70 degrees).

TAM= {(DIP+PlP+MCP) Flexion} – {Extension loss(DlP+PIP+MCP) + hyperextension}.

Assessment is done by comparing with the contralateral normal finger of the pre-operative assessment of the finger and is expressed as a percentage function.

The results are categorized as follows

TAM values	Grading
Equal to normal side	Excellent
TAM more than 75% of normal side	Good
TAM more than 50% to 74% of normal side	Fair
TAM less than 50% of normal side	Poor
TAM worse than before surgery	Worse

Because this system lacks numerical values for the excellent criteria it cannot be used for statistical analysis.

Only the proximal interphalangeal joint and distal interphalangeal joints were used for assessment in the Strickland and Glogovac system

TAM %=[{(PIP+DIP) flexion - (PIP+DIP) extension lag}/177] X100

Users of this system thought that MCP joint may contribute upto 30% of TAM and thus inflating the results. However others believe that inclusion of the MCP joint is important to the functional outcome and that its function is not always normal after flexor tendon injury.

A normal TAM of l77 degrees (100degrees for the proximal interphalangeal joint and 75 degrees for the distal interphalangeal joint), is used for comparison.

The results are classified as follows

Original classification:

85- 100%	Excellent
70 – 84%	Good
50 – 69%	Fair
Less than 50%	Poor

Adjusted system

75- 100%	Excellent
50 – 74%	Good
25 – 49%	Fair
Less than 25%	Poor

The Buck Gramcko and the Louisville systems provide results divided into categorical data. Hence their statistical power is low.

The average flexor tendon results from result is as follows

Rehabilitation	Combined excellent / Good	Excellent	Good
Immobilization	20%		
Kleinert	64%	44%	20%
Palmar bar	88%	71%	17%
Duran	69%	53%	16%
Washington	81%	66%	15%
Active Mobilization	82%	58%	24%

]

Materials & Methods

MATERIALS AND METHOD

Study design: Prospective study

Period: August 2010 to August 2012.

Place: Institute for Research and Rehabilitation of Hand

& Dept. of Plastic Surgery,

Govt. Stanley Medical College and Hospital,

Chennai – 600 001.

Subjects: Patient treated in this institute.

Consent: Informed consent.

Participants: Multiple surgeons, physiotherapists and

anaesthesiologists.

Financial Assistance: Nil

All patients who presented to us with flexor tendon injuries within 24 hours were included.

Patients were allotted a treatment protocol as follows:

Monday, Wednesday, Fridays and Sundays: 4 strands modified cruciate suture with simple running epitenon sutures and early active mobilization protocol.

Tuesdays, Thursdays and Saturdays: Modified Kessler's suture with running epitenon sutures and immobilization and ultrasound therapy protocol.

INCLUSION CRITERIA

- Zone II flexor tendon injuries
- Fresh injuries {time lapse less than 24 hrs}

EXCLUSION CRITERIA

- Associated extensor injuries.
- Associated bone injuries.
- Associated brachial plexsus, high median or ulnar nerve injuries.
- Associated injuries to forearm or arm muscles.
- Revascularizations.
- Children's < 12 years.
- Mentally unstable and uncooperative patients.
- Delayed primary and secondary repair patients.

SURGICAL PROTOCOL

Surgical repair is done under axillary block. And pneumatic tourniquet control.

Loupe magnification of 3.3X or 4X is used

Suture material used:

Core suture: 4-0 prolene monofilament

Epitenon sutures: 6-0 prolene monofilament

After thorough debridement and making adequate incision for exposure the cut structures are identified and tagged.

The cut end of the tendon is located and if needed is delivered into the surgical site by either;

1. Milking:
    a. Massaging over the tendon pathway towards the laceration along with flexion of the finger and wrist.
2. Instrument retrieval:
    a. Skin hook
    b. Hemosatat
    c. Tendon retriever can be used to retrieve the tendon into the wound.

3. Incision made proximally at the distal palmar crease or in the palm and the tendon is rail-roaded into the defect with a silicon rod or infant feeding tube.

The retrieved tendon is held in place by transfixing it in place with a percutaneous needle.

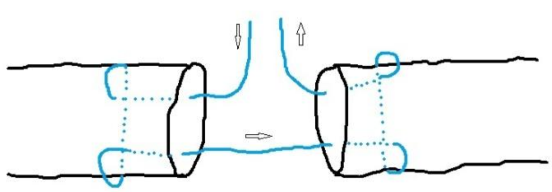
Tendon repair:

Both FDS and FDP were repaired if they were cut.

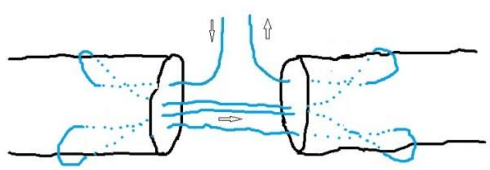
In zone 2A, where only the two slips of FDS are present. It is repaired with a horizontal suture while the FDP is repaired with core and epitenon sutures.

Core suturing is done by either

1. **Modified Kessler's suture**



2. **Modified 4 strand cruciate suture**



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Epitenon sutures are always simple running sutures.

Venting of the A2 of A4 pulleys are done if there is a need for exposure or hindrance to tendon gliding. A maximum of upto 50% venting is done.

Nerve repair is done with 7-0 prolene simple interrupted epineural sutures whenever the digital nerve is cut.

The tourniquet is released and hemostasis is attained. Skin is closed with nylon 3-0 horizontal mattress sutures over SegMuller drains .Generous padding is given. A below elbow dorsal slab with Plaster of Paris is given. The wrist is kept at neutral position, the MCP at 70-90 degrees flexion and the interphalangeal joints at slight flexion or extension. The hand is kept in strict elevation to reduce edema.

PROTOCOL FOR POST-OPERATIVE REHABILITATION

Protocol 1: Immobilization and Ultrasound

Ultrasonography is based on the principle of piezo electric effect. It produces micro streaming which has an effect in tendon healing. Similarities exist between early mobilization and ultrasound therapy by way of tendon healing. Safe and early application of ultrasound in tendon healing had been proved in many animal studies. We use Pulsed ultrasound of 3 Mhz frequency and administered for5 minutes daily and 6 days a week. After 3 weeks active & guarded passive mobilization was started under supervision of a physiotherapist. After 6 weeks resisted exercises were started.

Protocol 2: **Early Active Mobilization Protocol**

Assessment of the suture line is made on the fifth day. If it is found to be good, passive flexion exercises are started. Supervised sessions of active flexion are started by day 7 with blocking. “Place and hold exercises” (the finger is bent passively into a position and the patient is asked to hold the finger in the same position)are also commenced at 7 days. The block is progressively reduced over the next 3 weeks. The splint is removed at 3 weeks and full active flexion exercises are started. Passive extension is started at 6 weeks to correct residual tendon shortening or extension lag.

POST-OPERATIVE ASSESSMENT

Analysis is done at the end of 8 weeks using **modified Strickland’s criteria**

TAM % = [{(PIP+DIP) flexion - (PIP +DIP) extension lag}/177] X100

75- 100%	Excellent
50 – 74%	Good
25 – 49%	Fair
Less than 25%	Poor

Observations & Results

ZONE II INJURIES

Index Finger -FDP&FDS Injury

Index Finger - On Flexion

Little Finger
Both Tendon Injury

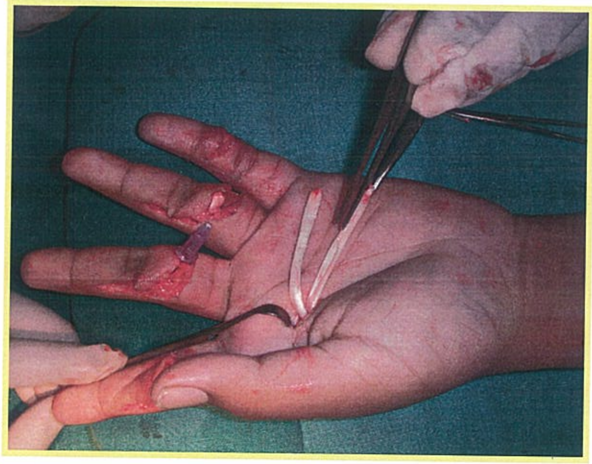
Little Finger Injury
On Flexion

Index & Mid Finger
Both Tendon Injury

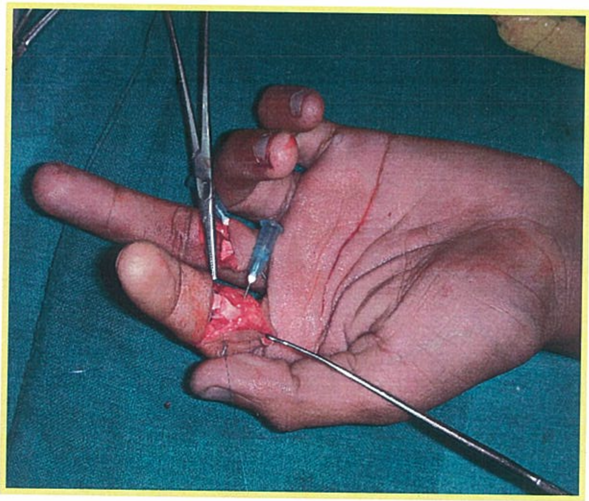
Little Finger
Both Tendon Injury

PER OPERATIVE

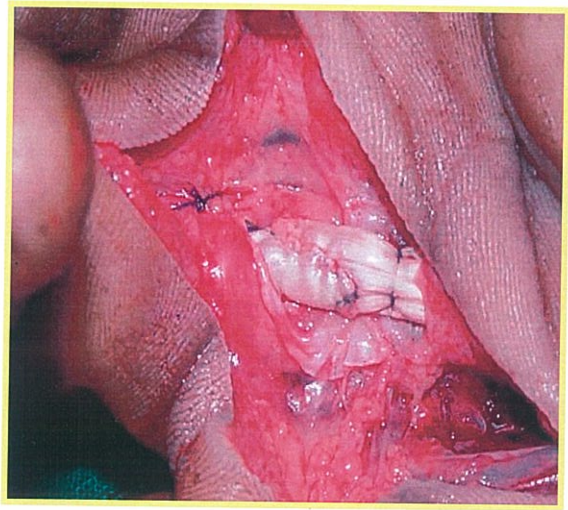
Tendon Retrieval



Tendon Retrieval - Four Finger Injury

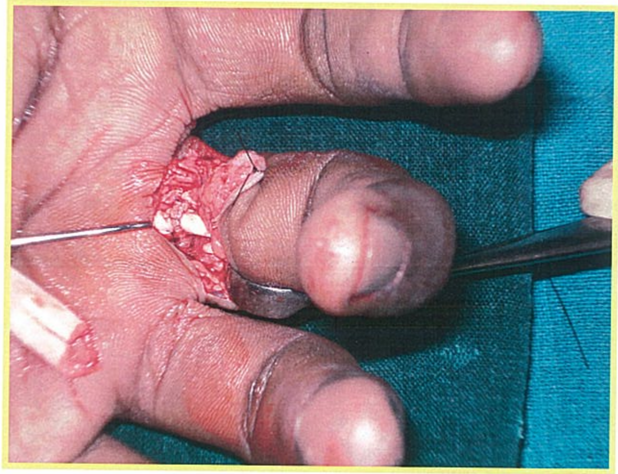


Tendon Repair



After Tendon Repair

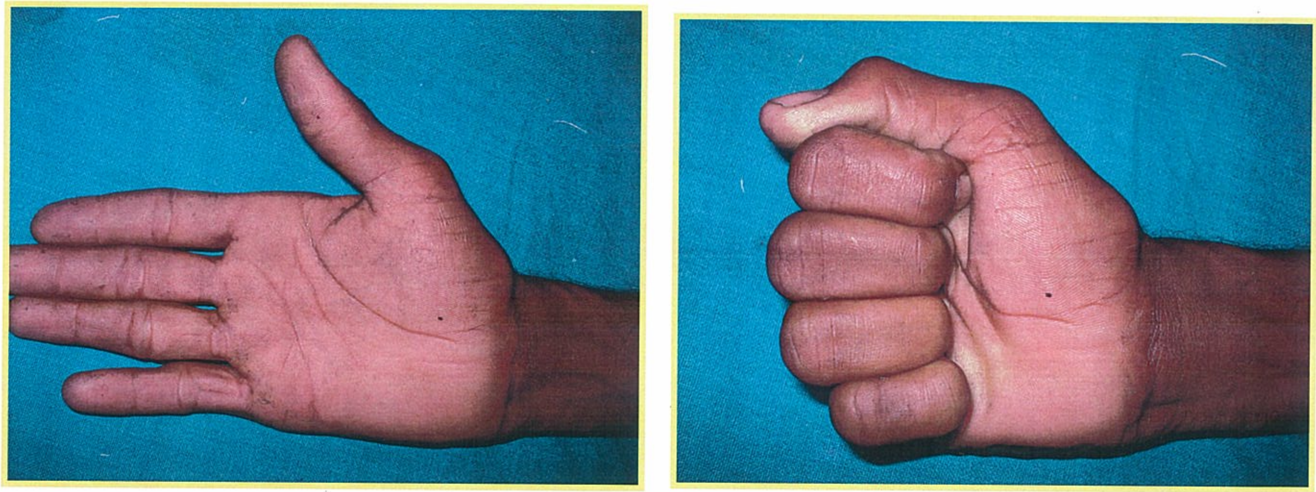
PER OPERATIVE



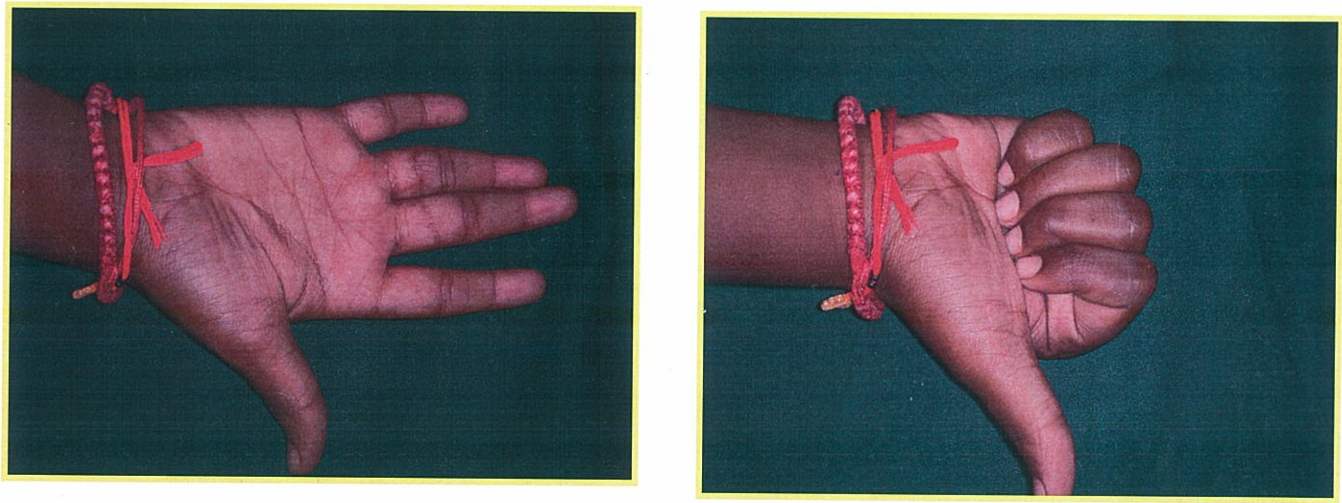
After Repair

After Repair - Index and Mid Fingers

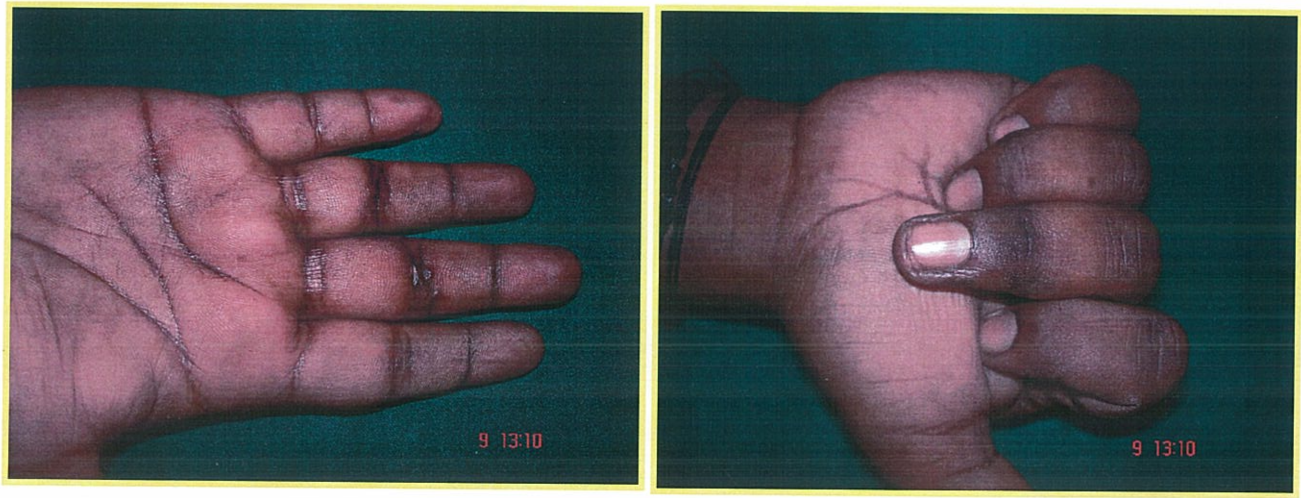
POST OPERATIVE ASSESSMENT



8 Weeks Post Repair –Little Finger



After 10 Weeks - Mid & Ring Fingers



After 8 Weeks - Mid Finger FDP - Not Acting

OBSERVATION AND RESULTS

In this study, there have been a total of 47 patients.

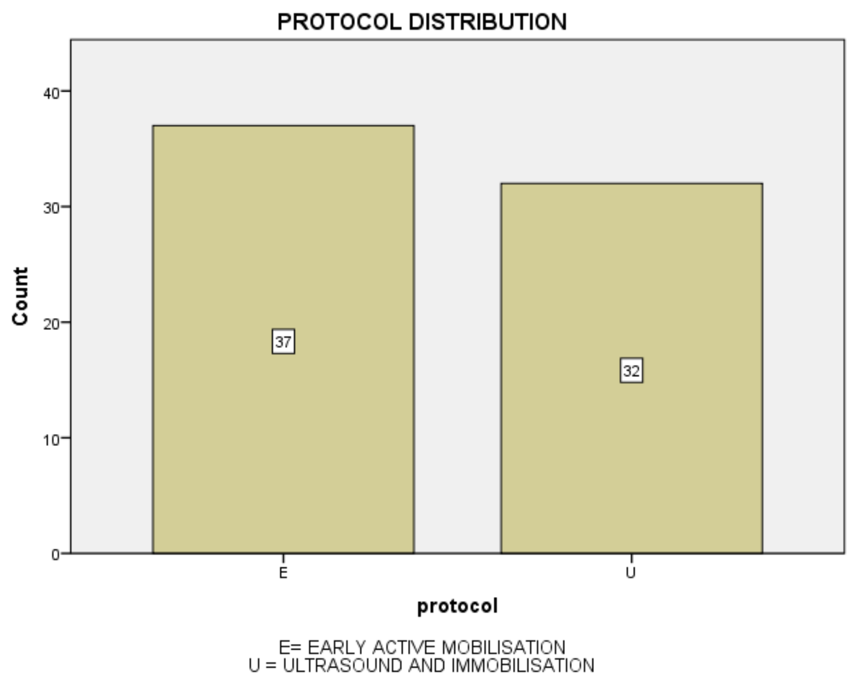
A total of 69 fingers were repaired.

Protocol wise distribution:

The total 69 finger were distributed to the two protocols as follows:

Early active mobilization – 37 patients

Ultrasound and immobilization – 32 patients



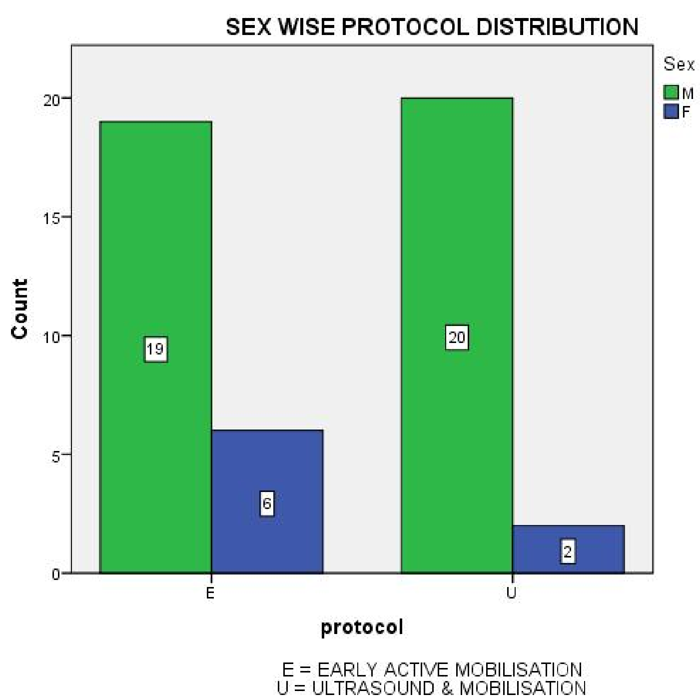
Age Distribution:

Most commonly affected age group was between 20 -30 with 24 patients (51.06%). Youngest patient was 13 and the oldest 65 years old. Mean age was 28.79 years.

Handedness was nearly equal with right hand (25) marginally more than the left.

Sex distribution:

Men were more commonly injured . n= 39 (87.5%)



Pattern of finger injury:

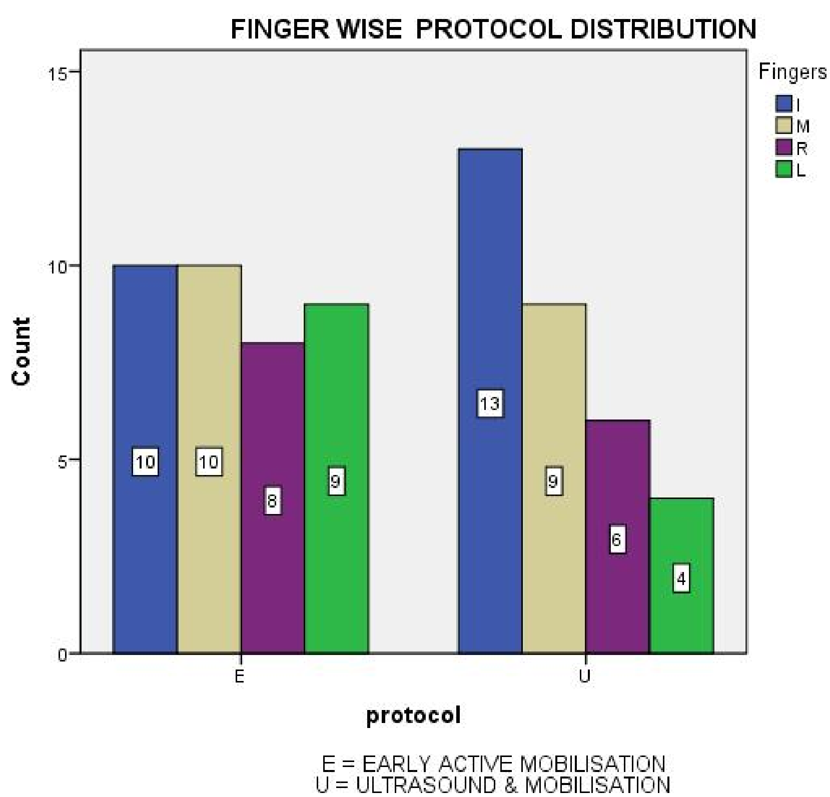
All four finger injuries in 2 patients.

Two finger injury in 16 patients.

Single finger injury in 29 patients.

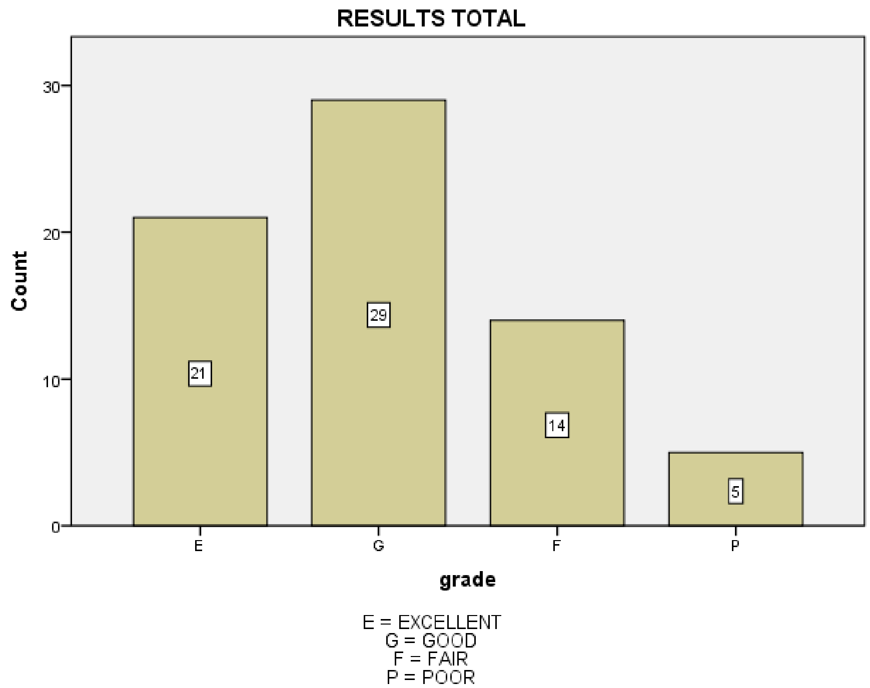
The index finger was the most commonly injured finger.

	Early Active Mobilisation	Ultrasound & immobilisation
Index	10	13
Mid	10	9
Ring	8	6
Little	9	4



RESULTS ANALYSIS

Overall Result

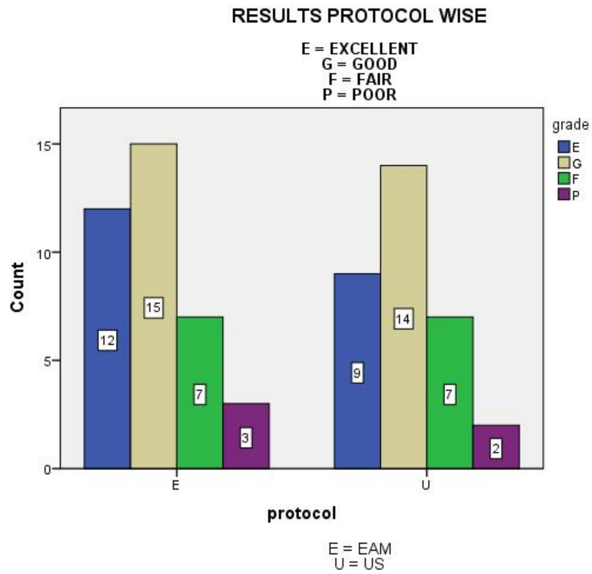


RESULTS	NUMBER	PERCENTAGE
Excellent	21	30.43
Good	29	42.02
Fair	14	20.28
Poor	5	7.24

An overall GOOD TO EXCELLENT OUTCOME was seen in a total of 72 % (50) fingers.

Fair outcome in 14 fingers and poor results in 5 fingers.

Protocol-Wise Result



Results	Early Active Mobilisation	Ultrasound & immobilisation
Excellent	12(32.43%)	9(28.12%)
Good	15(40.54)	14(43.75%)
Fair	7(18.91%)	7(21.87%)
Poor	3(8.1%)	2(6.25%)

Early Active Mobilisation protocol:

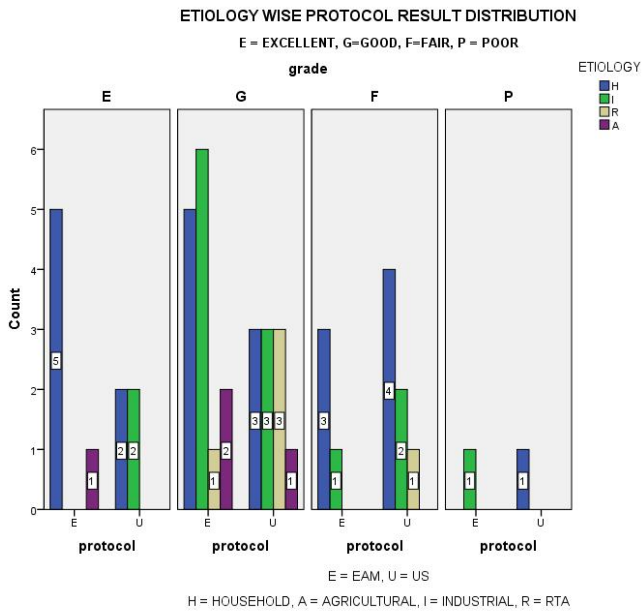
GOOD TO EXCELLENT results were obtained in 73% (17) fingers.

Fair outcome in 7 fingers and poor results in 3 fingers.

Ultrasound & immobilization protocol:

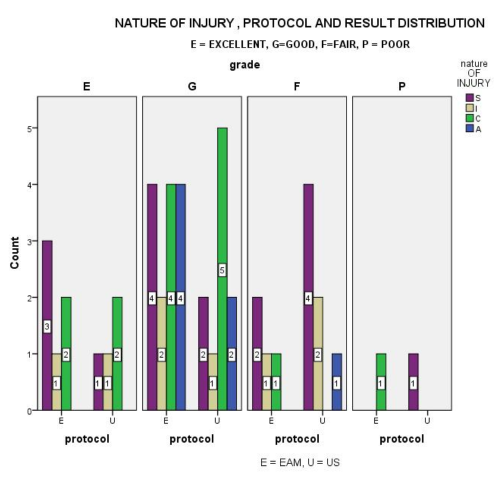
GOOD TO EXCELLENT results were obtained in 72% (23) fingers. Fair outcome in 7 fingers and poor results in 2 fingers.

Etiology Protocol Results



Household injuries are the most in both protocols. House hold and industrial accidents produced good to excellent results in both protocols in 61% and 52% respectively. Poorer results in both the protocols were obtained with road traffic accidents.

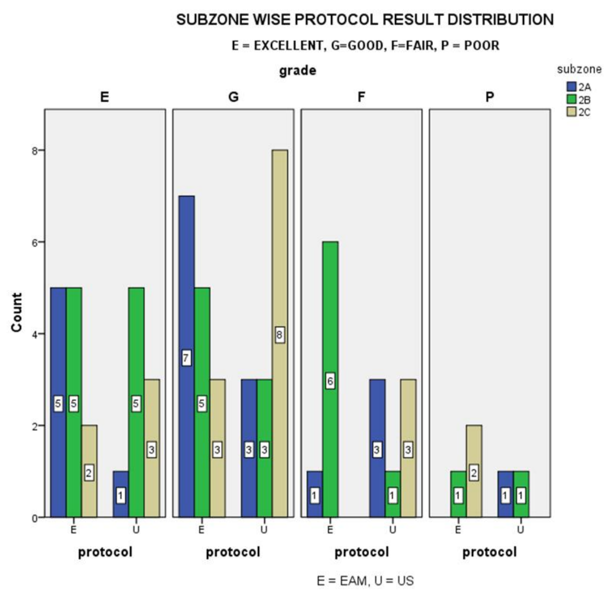
Nature of Injury, Protocol And Result Distribution



Slicing injuries were the most common. Though no specific type of the four was found to produce poorer results in both protocols.

Subzone Wise Protocol Result Distribution

Early active mobilization	Excellent	Good	Fair	Poor
2A	5	7	1	0
2B	5	5	6	1
2C	2	3	0	2
Ultrasound & immobilisation				
2A	1	3	3	1
2B	5	3	1	1
2C	3	8	3	0



Early active mobilization protocol:

Injuries in zone 2A produced better results with this protocol.

While 2B injuries did not show any specific patterns, 2C injuries produced more poor to fair results.

Ultrasound & immobilisation protocol:

2A injuries produced more fair to good results.2B injuries proving more good to excellent results. 2C zone injuries produced more results in the fair to good band in this protocol.

Complications:

Complication	**Early active mobilization protocol**	**Ultrasound & immobilisation protocol**
Adhesion	6 (16.8%)	4(12.5%)
Rupture	3(8.1%)	1(3.1%)

Early active mobilization protocol:

6 patients who produced fair results had adhesion, while 3 patients who had poor results had tendon rupture.

Ultrasound & immobilisation protocol:

4 patients who produced fair results had adhesion, while 1 patient who had poor results had tendon rupture.

Adhesions were managed with tenolysis and ruptures by secondary repair in 3 cases and tendon graft reconstruction in one case.

Discussion

DISCUSSION

Numerous experimental and clinical studies in the literature have produced 60 to 80% good to excellent results with the multi strand core suture with epitenon sutures and Early mobilization protocols

Similar studies to the 2 strand core suture with epitenon sutures and Ultrasound and immobilisation protocols have shown results of 45 to 60% in the literatures.

In our clinical study we have been able to produce good to excellent results in 73%.of the patients who underwent the modified 4-strand core suture with epitenon sutures and Early Active Mobilisation protocol. Modified Kessler’s 2- strand core suture with epitenon sutures and Ultrasound & immobilization protocol yielded good to excellent results in 72% cases.

Adhesions of the repaired tendon is identified at around 20 to 40% in the multi strand core suture with epitenon sutures and Early mobilization protocols in the literatures. Similar rates are mentioned for 2 strand core suture with epitenon sutures and Ultrasound and immobilisation protocols also.

In our clinical study adhesion rates were 16.5% and 12.5% for modified 4-strand core suture with epitenon sutures and Early Active

Mobilisation protocol and. Modified Kessler's 2- strand core suture with epitenon sutures and Ultrasound & immobilization protocol respectively.

Incidence of tendon rupture is in the range of 0-46% and0-9% % for Early Active Mobilisation protocol and Ultrasound & immobilization protocol respectively.

In our clinical study, the rates of tendon rupture was 8.1% and 3.1% for modified 4-strand core suture with epitenon sutures and Early Active Mobilisation protocol and Ultrasound &Modified Kessler's 2- strand core suture with epitenon sutures and Ultrasound & immobilization protocol respectively.

Though much ink has been shed about repair of two tendons in zone 2C by many authors, especially Tang et al., our good to excellent results were a combined 65% for protocols put together.

Though statistical comparison of the protocols on the basis of many factors, were done. The results did not show any significant changes in the results obtained by them.

The complications that occurred in our study are comparable to other studies. Adhesions were managed with tenolysis and ruptures by secondary repair in 3 cases and tendon graft reconstruction in one case.

Conclusion

CONCLUSION

1. The 4- strand modified cruciate core suture with simple running epitenon suture method with the Early Active mobilization physiotherapy protocol produces results that are comparable to international studies.

2. These results are at par with the 2 strand modified Kessler sutures with simple running epitenon suture method with the immobilization and ultrasound therapy protocol used in our institute.

3. Both the protocols yield results well within the accepted limits.

4. Complication rates can be minimized by careful monitoring of the patient.

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Proforma

STUDY – PROFORMA

Name: P.S.No.:

Age: Sex:

Date of injury: Date of surgery:

Address:____

____

____

Tel no:

MODE OF INJURY:- Industrial (I) / Household (H) /RTA (R)/ agricultural (A)

NATURE OF INJURY: Crush (C)/ lncised (I) / Slicing (S) / Avulsion.(A)

FINGER INJURED : single / multiple

Index / Mid / Ring / Little

Total:

SKIN LOSS: yes /no

WOUND CONTAMINATED: Yes /N0

TENDON ASSESSMENT:

SUB ZONES: 2A / 2B / 2C

INJURY: FDS / FDP / BOTH

PER OPERATIVE

CUT ENDS: Clean / Crushed

VINCULUM: Intact /Injured:

PULLEY INJURY: yes /no

DIGITAL NERVE INJURY: yes /no

DIGITAL VESSEL INJURY: yes / no

BONE FRACTURE: yes /no

INCISION: No extension /Zigzag /Neutral line extension /Skin crease (palmar crease)

TENDON: retrieval: none / instrument / rail roading

Method of suture: Modified Kessler (M) / modified 4 Strand cruciate (4)

Epitendinous suture-Done /Not done

Tendons repaired:	both/ FDP alone
Venting:	Yes / No
NERVE repair :	Yes /No
VESSEL ANASTAMOSIS:	Yes /No
BONE FIXATION:	Yes /No

POST OPERATIVE

Wound healing status

Day 3:	Yes /No
Day 5:	Yes /No
Day 10:	Yes /No

REHABILITATION PROTOCOL:

Early Active Mobilisation (E) /

Immobilisation& Ultrasound (U)

Post op assessment : Modified Stricklands criteria

% of TAM:

Grade : Excellent (E) / Good (G) / Fair (F) / Poor (P)

Master Chart

MASTER CHART

S.No.	P.S No	Name	Age	Sex	Side	Mode	Nature	Fingers	TOTAL	Subzone	Tendons	Nerve repair	suture	Protocol	TAM %	Grade
1	310514	Nagarajan	32	Male	Left	HOUSEHOLD	SLICING	INDEX,	2	2C	BOTH	YES	KESSLER - MODIFIED	ULTRASOUND & IMMOBILIZATION	79	EXCELLENT
								MID		2B	BOTH	YES	KESSLER - MODIFIED	ULTRASOUND & IMMOBILIZATION	75	EXCELLENT
2	310798	janakiraman	42	Male	Left	HOUSEHOLD	SLICING	INDEX,	2	2A	FDP	NO	4- STRAND CRUCIATE	EARLY ACTIVE MOBILIZATION	77	EXCELLENT
								MID		2A	FDP	NO	4- STRAND CRUCIATE	EARLY ACTIVE MOBILIZATION	76	EXCELLENT
3	310839	kandhan	18	Male	Left	RTA	AVULSION	RING	1	2C	BOTH	YES	KESSLER - MODIFIED	ULTRASOUND & IMMOBILIZATION	45	FAIR
4	310898	Udhayakumar	30	Male	Left	INDUSTRIAL	CRUSH	LITTLE	1	2A	BOTH	YES	4- STRAND CRUCIATE	EARLY ACTIVE MOBILIZATION	70	GOOD
5	311427	Parthiban	22	Male	Left	HOUSEHOLD	INCISING	MID	1	2C	BOTH	YES	KESSLER - MODIFIED	ULTRASOUND & IMMOBILIZATION	60	GOOD
6	311688	Ragu	36	Male	Right	INDUSTRIAL	CRUSH	INDEX	2	2B	FDP	NO	KESSLER - MODIFIED	ULTRASOUND & IMMOBILIZATION	61	GOOD
								MID		2B	FDP	NO	KESSLER - MODIFIED	ULTRASOUND & IMMOBILIZATION	75	EXCELLENT
7	312476	Rose mary	29	Female	Right	HOUSEHOLD	INCISING	RING	1	2A	BOTH	YES	4- STRAND CRUCIATE	EARLY ACTIVE MOBILIZATION	79	EXCELLENT
8	312728	Shankar	21	Male	Left	AGRICULTURAL	AVULSION	INDEX	2	2C	FDP	YES	KESSLER - MODIFIED	ULTRASOUND & IMMOBILIZATION	55	GOOD
								MID		2C	BOTH	NO	KESSLER - MODIFIED	ULTRASOUND & IMMOBILIZATION	52	GOOD
9	312732	Anbalagan	21	Male	Left	INDUSTRIAL	CRUSH	INDEX	2	2B	BOTH	YES	4- STRAND CRUCIATE	EARLY ACTIVE MOBILIZATION	45	FAIR
								MID		2B	BOTH	YES	4- STRAND CRUCIATE	EARLY ACTIVE MOBILIZATION	45	FAIR
10	313811	Suresh	18	Male	Right	HOUSEHOLD	SLICING	RING	1	2C	BOTH	YES	KESSLER - MODIFIED	ULTRASOUND & IMMOBILIZATION	45	FAIR
11	314666	Selvakumar	22	Male	left	HOUSEHOLD	SLICING	INDEX	1	2B	FDP	NO	4- STRAND CRUCIATE	EARLY ACTIVE MOBILIZATION	65	GOOD
12	315267	Velu	38	Male	Right	INDUSTRIALL	AVULSION	INDEX	1	2A	BOTH	YES	4- STRAND CRUCIATE	EARLY ACTIVE MOBILIZATION	65	GOOD
13	315670	Sudhakar	30	Male	Right	HOUSEHOLD	INCISING	INDEX	1	2C	FDP	NO	KESSLER - MODIFIED	ULTRASOUND & IMMOBILIZATION	80	EXCELLENT
14	316402	Santhosh	23	Male	Right	INDUSTRIAL	INCISING	INDEX	1	2B	BOTH	YES	4- STRAND CRUCIATE	EARLY ACTIVE MOBILIZATION	60	GOOD
15	316881	Gnanavel	23	Male	Right	INDUSTRIAL	CRUSH	INDEX	2	2B	BOTH	YES	KESSLER - MODIFIED	ULTRASOUND & IMMOBILIZATION	65	GOOD
								MID		2A	FDP	NO	KESSLER - MODIFIED	ULTRASOUND & IMMOBILIZATION	8	POOR
16	317644	Aanandhi	19	Female	Right	HOUSEHOLD	SLICING	RING	2	2C	FDP	NO	4- STRAND CRUCIATE	EARLY ACTIVE MOBILIZATION	60	GOOD
								MID		2C	FDP	NO	4- STRAND CRUCIATE	EARLY ACTIVE MOBILIZATION	10	POOR
17	317673	Rajesh	22	Male	Left	INDUSTRIAL	CRUSH	INDEX	1	2B	FDP	NO	KESSLER - MODIFIED	ULTRASOUND & IMMOBILIZATION	85	EXCELLENT
18	320308	Malayaisamy	42	Male	right	AGRICULTURAL	AVULSION	INDEX	1	2A	BOTH	YES	4- STRAND CRUCIATE	EARLY ACTIVE MOBILIZATION	55	GOOD
19	320655	Shanthi	40	Female	Left	HOUSEHOLD	SLICING	LITTLE	1	2B	FDP	NO	4- STRAND CRUCIATE	EARLY ACTIVE MOBILIZATION	45	FAIR
20	321263	Sivanadhan	55	Male	Left	INDUSTRIAL	CRUSH	RING	2	2C	BOTH	YES	4- STRAND CRUCIATE	EARLY ACTIVE MOBILIZATION	10	POOR
								MID		2B	BOTH	YES	4- STRAND CRUCIATE	EARLY ACTIVE MOBILIZATION	78	EXCELLENT
21	321454	Muthu	23	Male	Right	INDUSTRIAL	INCISING	INDEX	1	2A	FDP	NO	KESSLER - MODIFIED	ULTRASOUND & IMMOBILIZATION	45	FAIR
22	322157	prakash	30	Male	Right	HOUSEHOLD	SLICING	RING	1	2B	BOTH	YES	4- STRAND CRUCIATE	EARLY ACTIVE MOBILIZATION	78	EXCELLENT

23	322381	Rajesh kumar	21	Male	Left	HOUSEHOLD	SLICING	MID	1	2C	FDP	YES	KESSLER - MODIFIED	ULTRASOUND & IMMOBILIZATION	55	GOOD
24	323463	Rajaram	18	Male	Left	INDUSTRIAL	CRUSH	LITTLE	1	2B	FDP	NO	4- STRAND CRUCIATE	EARLY ACTIVE MOBILIZATION	68	GOOD
25	323471	Babu	43	Male	Left	RTA	AVULSION	LITTLE	2	2A	BOTH	YES	KESSLER - MODIFIED	ULTRASOUND & IMMOBILIZATION	55	GOOD
								RING		2A	BOTH	YES	KESSLER - MODIFIED	ULTRASOUND & IMMOBILIZATION	57	GOOD
26	323503	Gomathi.	27	Female	Left	AGRICULTURAL	CRUSH	LITTLE	1	2C	FDP	YES	4- STRAND CRUCIATE	EARLY ACTIVE MOBILIZATION	77	EXCELLENT
27	323965	Devendran	18	Male	Right	INDUSTRIAL	CRUSH	LITTLE	1	2C	BOTH	YES	KESSLER - MODIFIED	ULTRASOUND & IMMOBILIZATION	65	GOOD
28	324009	Bhavani	30	Female	Left	HOUSEHOLD	SLICING	LITTLE	1	2A	BOTH	YES	4- STRAND CRUCIATE	EARLY ACTIVE MOBILIZATION	62	GOOD
29	324014	Vasanth	24	Male	Right	HOUSEHOLD	SLICING	LITTLE	1	2A	FDP	NO	KESSLER - MODIFIED	ULTRASOUND & IMMOBILIZATION	35	FAIR
30	325406	Munusami	27	Male	Right	INDUSTRIAL	SLICING	MID	2	2C	BOTH	YES	4- STRAND CRUCIATE	EARLY ACTIVE MOBILIZATION	63	GOOD
								RING		2A	FDP	NO	4- STRAND CRUCIATE	EARLY ACTIVE MOBILIZATION	77	EXCELLENT
31	325536	Rajeshwari	30	Female	Right	HOUSEHOLD	SLICING	INDEX	1	2B	FDP	NO	KESSLER - MODIFIED	ULTRASOUND & IMMOBILIZATION	9	POOR
32	325756	Manikkam	61	Male	Left	AGRICULTURAL	CRUSH	MID	2	2B	FDP	NO	4- STRAND CRUCIATE	EARLY ACTIVE MOBILIZATION	59	GOOD
								RING		2B	FDP	NO	4- STRAND CRUCIATE	EARLY ACTIVE MOBILIZATION	85	EXCELLENT
33	326424	Chengunthan	41	Male	Left	RTA	CRUSH	INDEX	1	2C	FDP	YES	KESSLER - MODIFIED	ULTRASOUND & IMMOBILIZATION	58	GOOD
34	326473	Pandurangan	72	Male	Left	HOUSEHOLD	CRUSH	LITTLE	1	2B	FDP	NO	4- STRAND CRUCIATE	EARLY ACTIVE MOBILIZATION	80	EXCELLENT
35	327979	Palani	17	Male	Left	HOUSEHOLD	INCISING	MID	2	2A	FDP	NO	4- STRAND CRUCIATE	EARLY ACTIVE MOBILIZATION	56	GOOD
								RING		2A	FDP	NO	4- STRAND CRUCIATE	EARLY ACTIVE MOBILIZATION	56	GOOD
36	328497	Sulotchana	25	Female	Right	HOUSEHOLD	SLICING	INDEX	1	2A	FDP	NO	KESSLER - MODIFIED	ULTRASOUND & IMMOBILIZATION	38	FAIR
37	330210	Ayathee	35	Male	Right	RTA	CRUSH	INDEX	1	2C	FDP	NO	KESSLER - MODIFIED	ULTRASOUND & IMMOBILIZATION	47	GOOD
38	330278	Vijayakumar	25	Male	Right	HOUSEHOLD	SLICING	MID	2	2B	BOTH	YES	KESSLER - MODIFIED	ULTRASOUND & IMMOBILIZATION	27	FAIR
								RING		2B	BOTH	YES	KESSLER - MODIFIED	ULTRASOUND & IMMOBILIZATION	58	GOOD
39	330279	Vijayakumar	25	Male	Right	INDUSTRIAL	INCISING	MID	2	2C	BOTH	YES	KESSLER - MODIFIED	ULTRASOUND & IMMOBILIZATION	38	FAIR
								RING		2B	BOTH	YES	KESSLER - MODIFIED	ULTRASOUND & IMMOBILIZATION	81	EXCELLENT
40	330721	Adesh kumar	20	Male	Right	INDUSTRIAL	CRUSH	LITTLE	1	2A	FDP	NO	4- STRAND CRUCIATE	EARLY ACTIVE MOBILIZATION	59	GOOD
41	331193	Venkatesan	23	Male	Right	INDUSTRIAL	CRUSH	INDEX	1	2C	FDP	YES	KESSLER - MODIFIED	ULTRASOUND & IMMOBILIZATION	75	EXCELLENT
42	331925	Koteswaran	21	Male	Left	HOUSEHOLD	SLICING	INDEX	2	2B	FDP	NO	4- STRAND CRUCIATE	EARLY ACTIVE MOBILIZATION	39	FAIR
								MID		2B	FDP	NO	4- STRAND CRUCIATE	EARLY ACTIVE MOBILIZATION	38	FAIR
43	332132	Arumugam	18	Male	Right	HOUSEHOLD	SLICING	INDEX	4	2A	BOTH	YES	KESSLER - MODIFIED	ULTRASOUND & IMMOBILIZATION	65	GOOD
								MID		2A	BOTH	YES	KESSLER - MODIFIED	ULTRASOUND & IMMOBILIZATION	75	EXCELLENT
								RING		2B	BOTH	YES	KESSLER - MODIFIED	ULTRASOUND & IMMOBILIZATION	75	EXCELLENT
								LITTLE		2C	BOTH	YES	KESSLER - MODIFIED	ULTRASOUND & IMMOBILIZATION	62	GOOD
44	332422	Vignesh	13	Male	Right	HOUSEHOLD	INCISING	INDEX	4	2A	FDP	NO	4- STRAND CRUCIATE	EARLY ACTIVE MOBILIZATION	37	FAIR
								MID		2A	FDP	NO	4- STRAND CRUCIATE	EARLY ACTIVE MOBILIZATION	80	EXCELLENT

								RING		2B	BOTH	YES	4- STRAND CRUCIATE	EARLY ACTIVE MOBILIZATION	80	EXCELLENT
								LITTLE		2B	BOTH	YES	4- STRAND CRUCIATE	EARLY ACTIVE MOBILIZATION	45	FAIR
45	332544	Sridher	15	Male	Right	HOUSEHOLD	SLICING	LITTLE	1	2C	BOTH	YES	4- STRAND CRUCIATE	EARLY ACTIVE MOBILIZATION	85	EXCELLENT
46	332579	Raju	30	Male	Right	RTA	AVULSION	INDEX	1	2C	BOTH	YES	4- STRAND CRUCIATE	EARLY ACTIVE MOBILIZATION	70	GOOD
47	332656	Anuradha	38	Female	Left	HOUSEHOLD	AVULSION	INDEX	2	2B	FDP	NO	4- STRAND CRUCIATE	EARLY ACTIVE MOBILIZATION	70	GOOD
								MID		2B	FDP	NO	4- STRAND CRUCIATE	EARLY ACTIVE MOBILIZATION	12	POOR

Master Chart Variables

P.S No	Plastic surgery registration number
Mode	Mode of injury
Nature	Nature of Injury
Total	Total number of fingers injured
Tendons	Tendons injured